from Tresca's "flow;" Clarke's two estimates accord more nearly with the theoretical value; while Listing's, which is the latest of all, gives an agreement which is virtually exact. If we start from his estimate (1 : 288.4), we get $g = \frac{4\pi^2 \times 288.4}{(86164.1)^2} r = 32.086$ ft. Ganot's value is 32.088.ft. It can hardly be believed that such a coincidence is merely accidental. If it is indicative, as I have supposed, of inter-molecular æthereal action, it has an important bearing on tidal equilibrium, and it shows that Earth's shape and rigidity were not fixed in any past age, but are at all times adjusted to the requirements of internal elasticity and external attractions. Any arguments which may be adduced in favor of such an adjustment may be urged, *a fortiori*, in support of the flow and thrust of a plastic material like ice. The velocity of terrestrial rotation, in the mean latitude which Prof. H. C. Lewis has indicated for the terminal moraine in Pennsylvania, is more than 1000 feet per second. The centrifugal force consequent upon such a velocity, together with the thrust of an ice-cap which extended to the pole, must greatly facilitate glacial flow. The equilibrating forces would work upon local glaciers, in the same way as upon a general ice-cap.

The Classification of the Ungulate Mammalia. By E. D. Cope.

(*Read before the American Philosophical Society, May 19, 1882.*)

In the present essay the osseous system is chiefly considered, and of this, the structure of the feet more than of any other part of the skeleton. The ungulata are here understood to be the hoofed placental Mammalia with enamel covered teeth, as distinguished from the unguiculate or clawed and the mutilate or flipper limbed, and the edentate or enamelless, groups. The exact circumscription and definition is not here attempted, though probably the brain furnishes an additional basis of it in the absence of the crucial, parietoöccipital, calcarine fissures, etc. Suffice it to say that it is on the whole a rather homogeneous body of mammalia, especially distinguished as to its economy by the absence of forms accustomed to an insectivorous and carnivorous diet, and embracing the great majority of the herbivorous types of the world.

The internal relations of this vast division are readily determined by reference to the characters of the teeth and feet, as well as other less important points. I have always insisted that the place of first importance should be given to the feet, and the discovery of various extinct types has justified this view. The predominant significance of this part of the skeleton was first appreciated by Owen, who defined the orders *Perisso-*

dactyla and *Artiodactyla*. Professor Gill* has also used these characters to a large extent, but without giving them the exclusive weight that appears to me to belong to them. Other authors have either passed them by unnoticed, or have correlated them or subordinated them to other characters in a way which has left the question of true affinity and therefore of phylogeny, in a very unsatisfactory condition. Much light having been thrown on these points by recent discoveries in paleontology, the results, as they appear to me, are here given.

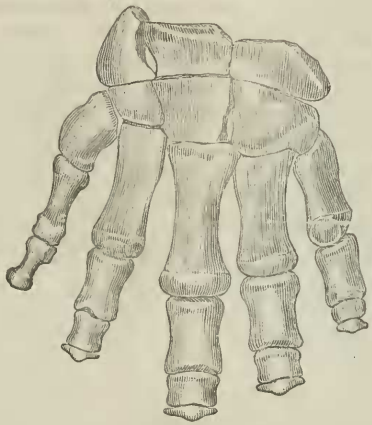


Fig. 1.

Fig. 1.—Left anterior foot of *Elephas africanus* (from De Blainville).

Carpus.—It is well known that in the *Perissodactyla* and *Artiodactyla*, the bones of the two rows of the carpus alternate with each other; that the lunar for instance rests on the unciform, and to a varying degree on the magnum, and that the scaphoides rests on the magnum and to some degree on the trapezoides and trapezium. It is also known that in the *Proboscidea*, another state of affairs exists; *i. e.*, that the bones of the two rows do not alternate, but that the scaphoides, lunar and cuneiform, rest directly on the trapezium and trapezoides, the magnum, and the unciform respectively. The preceding characters are sometimes included in the definitions of the respective orders. Further than this they have not been used in a systematic sense.

Professor Gill says of the carpus of the *Hyracoidea*, "carpal bones in two interlocking rows; cuneiform extending inwards (and articulating with magnum); * * * unciform and lunar separated by the interposition of the cuneiform and magnum." Professor Flower† gives a figure which justifies these statements, but neither the one nor the other agree with my

* Arrangement of the families of Mammals prepared for the Smithsonian Institution. Miscellaneous Collections 230. Nov., 1872.

† Osteology of the Mammalia, p. 266; fig. 92.

specimens. In the manus of a *Hyrax capensis* (from Verreaux, Paris), I find the following condition of the carpus. The bones of the two series are articulated consecutively, and not alternately; they do not interlock, but inasmuch as the magnum is a little narrower than the lunar, the latter is just in contact (anteriorly) with the trapezoides (centrale) on the one side, and the unciform on the other. My specimen agrees with Cuvier's figure of *Hyrax capensis* in all respects. It is probable that Professor

Fig. 2.

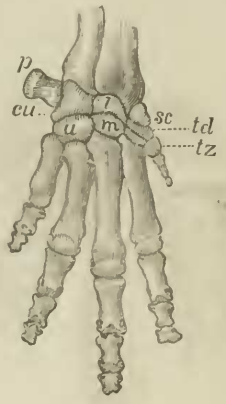


Fig. 3.

Fig. 2.—Left anterior foot of *Phenacodus primævus*, one-third natural size (original).

Fig. 3.—Right anterior foot of *Hyrax capensis*; (from Cuvier). *Sc.* scapuloid bone; *l.* lunar; *cu.* cuneiform; *p.* pisiform; *tz.* trapezium; *td.* trapezoides; *m.* magnum; *u.* unciform.

Flower has figured some other species under that name, which besides its peculiarities, is of smaller size than the *H. capensis* (see Fig. 3).

In April, 1875* I described the manus of *Coryphodon* (Bathmodon), showing that the lunar was supported below by the magnum and by parts of the unciform. This carpus has the characters of that of *Hyrax capensis*, with the last named articulation more extensive. This was the first description of the carpus of the *Amblypoda*. In February, 1876,† Professor Marsh described the carpus of *Uintatherium* (*Dinoceras*), and asserted that the bones "form interlocking series." He however states that "the magnum is supported by the lunar and not at all by the scaphoid," a state of things which does not belong to the interlocking carpus. The trapezoides does not join the lunar, but the unciform does so, as in *Coryphodon*. Professor Marsh's figure as to the articu-

* Systematic Catalogue of the vertebrata of the Eocene of New Mexico, p. 24 (U. S. Geol. Survey W. of 100th Mer.).

† Amer. Journal Sci. Arts. xi, p. 167; pl. vi., fig. 2.

lations of the magnum does not agree with his description, as it makes that bone articulate with the scaphoid. The second description is however correct, and the carpus is identical with that of *Coryphodon*. (Fig. 4.)

In the *American Naturalist*, June, 1882,* I have shown that the carpus of the *Condylarthra* is essentially like that of the *Hyracoidea*. (Fig. 2.)

Fig. 4.

Fig. 5.

Fig. 4.—Manus of *Coryphodon* (original). The cuneïform is imperfect.

Fig. 5.—Left posterior foot of *Elephas indicus*; (from Cuvier). *ca.* calcaneum: *a.* astragalus; *n.* navicular; *cu.* cuboid; *ec.* ectocuneïform; *mc.* mesocuneïform.

Tarsus.—In the tarsus of the *Perissodactyla* and *Artiodactyla* it is well understood that the cuboid extends inwards so as to articulate with the astragalus, giving the latter a double distal facet. It is also well known that the astragalus of the *Proboscidea* has but a single distal articulation, that with the navicular. It is, however, true that the cuboid is extended inwards, but that it articulates with the distal extremity of the navicular instead of that of the astragalus. It was shown by Cuvier that the astragalus of the *Hyracoidea* articulates with the navicular only, and that the cuboid is not extended inwards so as to overlap the latter. In 1873 Marsh† stated that the astragalus of the *Amblypoda* articulates with both cuboid and navicular. Finally I discovered in 1881,‡ that the astragalus of the *Condylarthra* articulates with the navicular only and that the cuboid articulates with

* Page 522.

† American Journal Science and Art, January, 1873.

‡ American Naturalist, 1881, p. 1017.

the calcaneum only. In the tarsus then there are four types of articula-

FIG. 6.

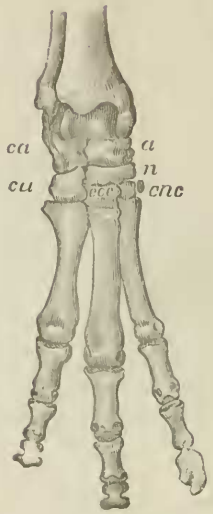


FIG. 7.

FIG. 6.—Left posterior foot of *Phenacodus primævus*, one-third natural size (original).

FIG. 7.—Right posterior foot of *Hyrax capensis* (from Cuvier). *Ca.* calcaneum; *a.* astragalus; *n.* navicular; *cu.* cuboid; *ccc.* ectocuneiform; *mc.* mesocuneiform; *enc.* entocuneiform.

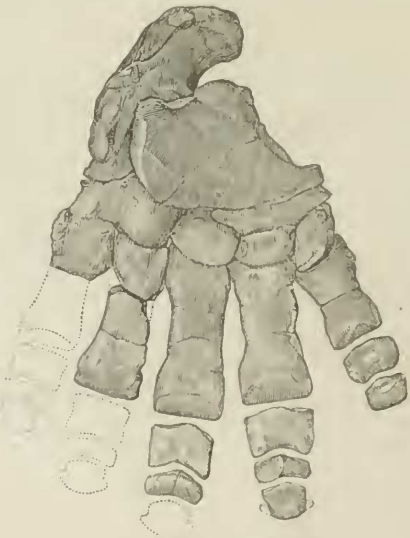


FIG. 8.

FIG. 8.—Posterior foot of *Coryphodon* (original).

tion, which are typified in the *Condylarthra*, the *Proboscidea*, the *Amblypoda* and the *Artiodactyla* respectively. (Figs. 5–9.)

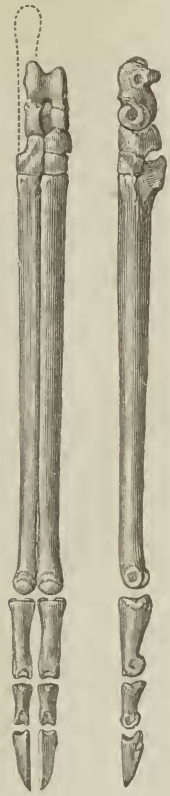


Fig. 9.

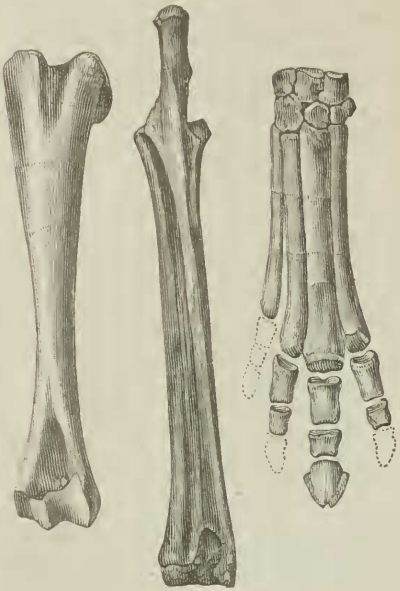


Fig. 10.

Fig. 9.—Hind foot of *Poëbrotherium labiatum* (original).
Fig. 10.—Fore leg and foot of *Hyracotherium ventieolum* (original).

Orders.—From the preceding considerations we derive the following definitions of the primary divisions of the Ungulata, which should be called orders. In the first place I find the diversity in the structure of the carpus to be greater in the relations of the magnum and scaphoides, than in the relations between the unciform and the lunar. In other words the trapezoides and magnum are more variable in their proportions than is the unciform. This is directly due to the fact that the reduction of the inner two digits is more usual than the reduction of the external two. I therefore view the relations of these bones as more characteristic. In the tarsus the really variable bone is the cuboid. It is by its extension inwards

that the additional facet of the astragalus is produced. Its relations will therefore be considered rather than those of the astragalus in framing the following definitions :

Order I. Scaphoides supported by trapezoides and not by magnum, which supports lunar. Cuboid articulating proximally with calcaneum only..... *Taxeopoda.*

Order II. Scaphoides supported by trapezoides, and not by magnum, which supports lunar. Cuboid extended inwards and articulating with the distal face of the navicular..... *Proboscidea.*

Order III. Scaphoides supported by trapezoides and not by magnum, which with unciform, supports the lunar. Cuboid extended inwards and articulating with astragalus..... *Amblypoda.*

Order IV. Scaphoides supported by magnum, which with the unciform also supports the lunar. Cuboid extended inwards so as to articulate with the astragalus..... *Diplarthra.*

The sub-orders are defined as follows :

I. TAXEOPODA.

There are two, perhaps three sub-orders of the *Taxeopoda;* the *Hyracoidea*, the *Condylarthra*, and perhaps the *Toxodontia.** The *Toxodontia* are however not sufficiently known for final reference.† The sub-orders are defined as follows :

A postglenoid process ; no fibular facet of calcaneum, but an interlocking articulation between fibula and astragalus ; ungual phalanges truncate..... *Hyracoidea.*

A postglenoid process ; no fibular facets on either calcaneum or astragalus ; a third trochanter of the femur ; ungual phalanges acuminate..... *Condylarthra.*

There are a good many other subordinate characters which distinguish the *Condylarthra*, which will be given in my forthcoming volume iv of the Hayden Survey, on the Tertiary Vertebrata of Western America.

II. PROBOSCIDEA.

There may be two sub-orders of this order, the *Proboscidea* and the *Toxodontia.* I do not know the Carpus of *Toxodon*, but if it does not differ more from that of the elephants than the tarsus does ; it is not entitled to subordinal distinction from the Proboscidea. The sub-order of *Proboscidea* is defined as follows :

A fibular articulation of the calcaneum ; no postglenoid process ; no third trochanter of femur..... *Proboscidea.*

* See my remarks on Toxodon, Proceedings Amer. Philosoph. Society, 1881, p. 402.

† The considerable resemblance between the dentition of *Toxodon* and *Hyrax* must not be overlooked.

III. AMBLYPODA.

The sub-orders of this order, as I pointed out in 1873, are two, defined as follows:

Superior incisor teeth; no ali-sphenoid canal; a third trochanter of femur; *Pantodonta.*

No superior incisors, nor ali-sphenoid canal, nor third trochanter of femur: *Dinocerata.*

The difference between the *Proboscidea* and the *Amblypoda* consists chiefly in that the navicular of the latter is shortened externally so as to permit the cuboid to articulate with the astragalus. The cuboid has the same form in both. The peculiar character of the navicular gives the astragalus a different form.

IV. DIPLARTHRA.

This order is called by some authors the Ungulata, but that name is also used in the larger sense in which it is here employed. This appears to be its legitimate application, as the name should, if possible, be used for hoofed Mammalia in general, as its meaning implies. The two well known sub-orders are the following:

Astragalus truncate distally; number of toes odd, the median one the largest..... ..... *Perissodactyla.*

Astragalus with a distal ginglymus; number of toes even, the median two largest..... *Artiodactyla.*

Phylogeny.—The serial arrangement of the bones of the carpus and tarsus seen in the *Taxeopoda*, is probably the primitive one, and we may expect numerous accessions to that order on further exploration of the early Eocene epochs. The modification seen in the more modern orders of *Perissodactyla* and *Artiodactyla*, may be regarded as a rotation to the inner side, of the bones of the second carpal row, on those of the first. This rotation is probably nearly coincident with the loss of the pollex, as it throws the weight one digit outwards, that is on the third and fourth digits, rendering the first functionally useless to a foot constructed solely for sustaining a weight in motion. The alternation of the two rows of carpals clearly gives greater strength to the foot than their serial arrangement, and this may probably account for the survival of the type possessing it, and the extinction of nearly all the species of the type which does not possess it. Here is applied again the principle first observed by Kowalevsky in the proximal metapodial articulations. This author shows that the types in which the metapodials articulate with two carpal or tarsal bones, have survived, while those in which the articulation is made with a single carpal or tarsal have become extinct. The double articulation is, of course, mechanically the more secure against dislocation or fracture.

As regards the inner part of the manus I know of no genus which presents a type of carpus intermediate between that of the *Taxeopoda* and

Amblypoda on the one hand, and the *Perissodactyla* and *Artiodactyla* on the other. Such will however probably be discovered. But the earliest *Perissodactyla*, as for instance *Hyracotherium*, *Hyrachyus* and *Triplopus*, possess the carpus of the later forms, *Rhinocerus* and *Tapirus*. The order *Amblypoda* occupies an interesting position between the two groups, for while it has the carpus of the primitive type, it has the tarsus of the later orders. The bones of the tarsus alternate, thus showing a decided advance on the *Taxeopoda*. This order is then less primitive than the latter, although in the form of its astragalus it no doubt retains some primitive peculiarities which none of the known *Taxeopoda* possess. I refer to the absence of trochlea, a character which will yet be discovered in the *Taxeopoda*, I have no doubt.

The *Taxeopoda* approach remarkably near the *Bunotheria*, and the unguiculate and ungulate orders are brought into the closest approximation in these representatives. In fact I know of nothing to distinguish the *Condylarthra* from the *Mesodonta*, but the ungulate and unguiculate characters of the two divisions. In the *Creodonta* this distinction is reduced to very small proportions, since the claws of *Mesonyx* are almost hoofs. Some of the genera of the *Periptychidæ* present resemblances to the *Creodonta* in their dentition also.

The facts already adduced throw much light on the genealogy of the Ungulate Mammalia. The entire series has not yet been discovered, but we can with great probability supply the missing links. In 1874 I pointed* out the existence of a yet undiscovered type of Ungulata, which was ancestral to the *Amblypoda*, *Proboscidea*, *Perissodactyla* and *Artiodactyla*, indicating it by a star only in a genealogical table. This form was discovered in 1881, seven years later, in the *Condylarthra*. It was not until later† that I assumed that the *Diplarthra* are descendants of the *Amblypoda*, although not of either of the known orders, but of a theoretical division with bunodont teeth.‡ That such a group has existed is rendered extremely probable in view of the existence of the bunodont *Proboscidea* and *Condylarthra*. That the *Taxeopoda* was the ancestor of this hypothetical group as well as of the *Proboscidea*, is extremely probable. But here again neither of the sub-orders of this group represent exactly the ancestors of the known *Amblypoda*, which have an especially primitive form of the astragalus not found in the former. In the absence of an ankle-joint, the *Amblypoda* are more primitive than any other division of the Ungulata, and their ancestors are not likely to have been more specialized than they. It is probable that a third sub-order of *Taxeopoda* has existed which had no trochlea of the astragalus, which I call provisionally by the name of *Platyarthra*.

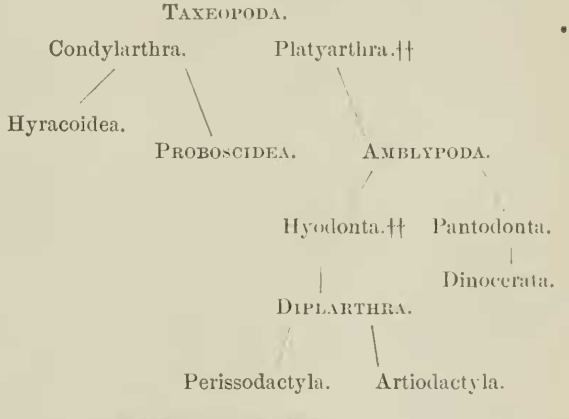
* Homologies and Origin of Teeth, etc., Journal Academy Nat. Science, Philada., 1874, p. 20.

† Report U. S. Geol. Survey W. of 100th Mer., p. 282, 1877.

‡ This hypothetical sub-order is called in the appended scheme, *Amblypoda Hyodonta*.

The preceding paragraphs were written in May of the present year. On my return home, September 1st, after an absence of three months, I find that various parts of the skeleton of *Periptychus** have reached my museum. On examination, I find that the astragalus of that genus fulfils the anticipation above expressed. *It is without trochlea,* and nearly resembles that of *Elephas.* As it agrees nearly with that of *Phenacodus* in other respects I only separate it as a family from the *Phenacodontidæ.* One other type remains to be discovered which shall connect the *Periptychidæ* and the hypothetical *Hyodonta,* and that is a Taxeopod without a head to the astragalus,—unless, indeed, the "*Hyodonta*" should prove to have such a head. I think the latter the less probable hypothesis, and hence retain the term *Platyarthra* for the hypothetical Taxeopod without trochlea or head of the astragalus.

These relations may be rendered clearer by the following diagram:



Third contribution to the History of the Vertebrata of the Permian formation of Texas. By E. D. Cope.

(*Read before the American Philosophical Society, September 15, 1882.*)

Since the publication of my second contribution to this subject,‡ I have described four additional species. These are, in Bulletin of the U. S. Geological Survey of the Territories;§ *Pantylus cordatus* and *Dimetrodon semiradicatus;* in the American Naturalist,‖ *Eryops reticulatus* and *Za-*

* See American Naturalist, October, 1882.

†† Hypothetical.

‡ Paleontological Bulletin, No. 32, Proceedings American Philosophical Society, 1880; the plates, 1881.

§ Vol. vi, 1881, p. 79.

‖ 1881, p. 1020.